An empirical comparison of behavioural responses from field and laboratory trials to institutions to manage water as a common pool resource.

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Abstract

There has been extensive debate in the experimental economics literature as to the validity of extending the results of student experiments to more complex real world settings, characterised by the economic behaviour of diverse participants. This study formally compares the behavioural responses of irrigator and student participants in such a complex real world setting.

Tisdell et al. (2004) combined the use of an environmental levy with community involvement in the formation of group agreements and strategies to explore the impact of information and communication on water use in a complex heterogeneous environment. Student participants in the experiments acted as farmers faced with monthly water demands, uncertain rainfall, possible crop loss and the possibility of trading in water entitlements. The treatments included (a) no information on environmental consequences of extraction, (b) the provision of monthly aggregate environmental information, (c) the provision of monthly aggregate extraction information and a forum for discussion, and (d) the public provision of individual extraction information and a forum for discussion giving rise to potential verbal peer sanctions. To account for the impact of trade the treatments were blocked into two market types: no trade and a closed call clearance market. The simulated environmental flows provide equal public benefits to all experimental participants. The cost to the community of altering the natural flow regime to meet extractive demand was socialised through the imposition of an environmental levy equally imposed on all players.

This research replicated that study using an irrigator subject pool drawn from land holders in the Daly River, Katherine and Darwin Catchments, Northern Territory Australia. The research findings are in accord with the generally received wisdom that the implications of laboratory findings should be interpreted cautiously when extrapolated beyond the specific institutional setting of the experiment. In applying the findings of this research to specific catchments practitioners need to be mindful of the particular characteristics of the catchment and the transaction costs and possible institutional constraints and opportunities associated with providing an effective forum for group communication and the dissemination of information.

The study also found that the magnitude, direction and sign of the between treatment field results were generally in accord with the student laboratory sessions. The increased level of the environmental levy, a corollary of the closed call treatment combined with aggregate information and the substantial reduction in the levy associated with the introduction of individual information were notable diversions. The level of voluntary accordance with the group crafted social compact was also substantially higher in the field experiments compared to the student sessions. In conclusion, an improved understanding of social connections, group norms reputation and reciprocity in the field settings and the translation into policy praxis is the subject of ongoing research, as is the comparison of student-based laboratory experiments with those in the field.

KEYWORDS: Australian water reform, common pool resources, communication, field experiments, experimental economics

POLICY BACKGROUND

The National Water Initiative (NWI) was ratified in 2004 by the Commonwealth of Australia and the Governments of New South Wales, Victoria, Queensland, South Australia and the Australian Capital Territory; the Northern Territory and Tasmania became signatories in June 2005. The NWI sets out objectives, outcomes and actions for the ongoing process of Australian water reform, and timelines to achieve this reform. The objective of the NWI is the development of:

> "*A nationally-compatible, market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes*". (NWI clause 23)

In relation to water markets and trading, States and Territories have agreed to establish water market and trading arrangements that will (NWI clause 58):

1) facilitate the operation of efficient water markets and the opportunities for trading, within and between States and Territories, where water systems are physically shared or hydrologic connections and water supply considerations will permit water trading;

2) minimise transaction costs on water trades, including through good information flows in the market and compatible entitlement, registry, regulatory and other arrangements across jurisdictions;

3) enable the appropriate mix of water products to develop based on access entitlements which can be traded either in whole or in part, and either temporarily or permanently, or through lease arrangements or other trading options that may evolve over time;

4) recognise and protect the needs of the environment; and

5) provide appropriate protection of third-party interests.

The Northern Territory government is currently initiating process to comply with the NWI obligations. These include a work plan to implement the NWI, an assessment of National Competition Policy, the establishment of NWI performance indicators, accounting, trading, entitlements and registers are being examined and a Water Resources Strategies plan is being prepared. Water trading is anticipated to take place in the Northern Territory, although there is currently there is no water trading occurring.

The recent advances in the exchange of transferable water entitlements as a policy tool for management in a mature water market (Randall 1983), has manifested as limited opportunities for policy makers to gain experience and expertise in design, testing and field implementation. Appraisals of their relative importance in policy portfolios have also been informal and at times *ad hoc*. Although the analysis of water market performance has improved, simple rules and evaluation protocols to identify *a priori* the relative advantages over other instruments to resolve specific environmental problems and coordination dilemmas have not yet emerged. We advance the notion that experimental economics provides a rapid, formal, robust and repeatable examination of policy options under laboratory conditions, providing a comparison of predicted outcomes with direct observations of economic behaviour.

Managing the environmental consequences of water extraction from rivers is complex and likely to require a combination of economic instruments and community involvement in coordinating aggregate extraction strategies (Common 1995, Randall 1981). Water, as a common pool resource, is partially characterised by enforceable, exclusive and transferable rights to utilise a defined amount from the total available water. In addition, a substantial component of available water confers a mutually shared, environmental benefit to the owners of those extractive rights, which is

both non-excludable and subject to rival consumption (or subtractable usage). Excess aggregate irrigation extraction by individuals imposes a reduction of those mutually shared benefits.

INTRODUCTION

The research described in this paper examined the formal testing of applied Australian water policy, which requires developed strategies to account for the social, economic and biophysical complexities of water as a common pool resource. Water extraction for irrigation in many Australian river systems is adversely altering the flow pattern, resulting in an environmental externality. In these studies the cost of the externality was socialized equally among the water extractors. The research explores the way farmers may react to such a common pool problem compared with students in replicate experimental settings. The paper compares the results of identical water trading economic experiments of Tisdell, Ward and Capon (2004) employing undergraduate university students with the results of field experiments which draw on actual irrigators as participants. The experimental setting and results of the student laboratory sessions are detailed in Tisdell *et al.* (2004).

The experimental design combined the use of an environmental levy with community involvement in the formation of group agreements and strategies to explore the impact of information and communication on water use in a complex heterogeneous environment. Student participants in the experiments acted as farmers faced with monthly water demands, uncertain rainfall, possible crop loss and the possibility of trading in water entitlements. The treatments included (a) no information on environmental consequences of extraction, (b) the provision of monthly aggregate environmental information, (c) the provision of monthly aggregate extraction information and a forum for discussion, and (d) the public provision of individual extraction information and a forum for discussion giving rise to potential verbal peer sanctions. To account for the impact of trade the treatments were blocked into two market types (i) no trade and (ii) closed call clearance market. The cost to the community of altering the natural flow regime to meet extractive demand was socialised through the imposition of an environmental levy equally imposed on all players.

This paper reports the results of replicating the experimental protocols, processes and decision environment developed by Tisdell *et al.* (2004), with irrigators in the Northern Territory. Irrigators participated in a remote replication of the original student experiments using a mobile laboratory of wireless networked laptop computers.

1 EXPERIMENTAL ASSESSMENT OF RESOURCE POLICY OPTIONS

Experimental economics yields a formalised, replicable approach to rapidly assess alternate policy directives, typically expressed as market outcomes, prior to catchment-wide implementation (Dinar *et al*. 1998). The methodology provides a relatively inexpensive means of institutional analysis coupled with substantially reduced time horizons. Well-designed experiments allow for the evaluation of participant willingness to exchange, the stability of diverse institutional structures across an array of market conditions, the efficacy of policy directives and highlights potential detrimental outcomes, which may compromise a water reform process. The application of experimental results can provide water authorities and decision-makers with sufficiently robust information to circumvent or mitigate the consequences of inappropriate policy commitments, minimising the time for trial and error and associated social expense (Murphy *et al*. 2000).

Plott and Porter (1996) highlighted an additional advantage of evaluating and developing economic policies using experimental methods. Plott and Porter (1996) argued that designing an experiment requires specification of the details of a policy and the economic environment the policy is designed

for. Accordingly, this process raises questions that might never be asked until the policy is actually implemented. ‘‘*The very act of creating an experiment means that issues of timing, systems for gathering and reporting information, methods for resolving conflicts and uncertainties, and other institutional details that give policy life are specified in operational* (*as opposed to abstract*) *terms*’’ (Plott and Porter, 1996, p. 237).

Roth (1995) argued that policy experiments are generally motivated by the type of policy question that interests regulatory agencies and the experimental environment is typically designed to resemble those aspects of the naturally occurring environment that are the policy target. This enables economists to utilize the scientific method in formulating policy advice, especially when existing theories are inadequate.

Researchers, including Dinar *et al.* (1998) and Murphy *et al*. (2000), have designed and employed experimental water markets to explore the policy implications of water trade in the western United States. Experimental water markets can be used to examine new market institutions, policy reforms, and even simulate environmental conditions such as periods of high rainfall or drought.

The conventional wisdom influencing economic experimental settings has generally relied on abstract experimental settings, free of connotation or context. The experimental control of context is achieved through unambiguous, parsimonious instruction sets, sufficient to enable task completion whilst avoiding leading examples. Instruction sets carefully articulate the rules of exchange in anonymous settings with autonomous agents, specific participant endowments, transparent payments and credible threats. The primary instruction focus is to induce behaviour to be expressed as a single monetized decision metric. The approach attempts to resolve the classical experimental problem of unaccounted confounding, such that unpredictable behavior can therefore be reliably ascribed to theoretical deficits rather than deficits in the experimental design (Harrison and List 2004, Shogren 2006). Participants are required to follow the instructions and experimental scripts carefully and rigorously. As Shogren (2006, p.164) noted that “*context can be desirable if the goal is to avoid creating an environment that is too sterile and too abstract from reality*”. Lowenstein (1999) states that even sterile, abstract settings, lacking in tangible social cues, are subject to variable, uncontrolled participant interpretation. Careful introduction of context avoids participants creating context of their own, or mental enhancement, which has the potential to motivate behaviour in unexpected ways. The dilemma in experimental design is summarized by Friedman and Sunder (1994), who note:

> “Your first instinct in designing an experiment probably will be to pursue realism – designing the laboratory environment to resemble as closely as possible a real-world environment of substantive economic interest…(o)n the other hand, if you are a theorist, your first instinct is to design an experiment that replicates as closely as possible the assumption of the underlying theory.” (Friedman and Sunder 1994)

In a consideration of experimental context, Eckel and Grossman (1996) state:

> “As experimenters, we aspire to instructions that most closely mimic the environments implicit in the theory, which is inevitably a mathematical abstraction of an economic situation. We are careful not to contaminate our tests by unnecessary context. But it is also possible to use experimental methodology to explore the importance and consequence of context…. This may be particularly true for the investigation of other-regarding behavior….” (Eckel & Grossman 1996; cited in Krause *et al*. 2003)

In contrast to supporting evidence from laboratory experiments (*inter alia* Smith 2002), policy makers have questioned the validity of interpreting abstract experimental results into an operational praxis, implemented in complex real world settings comprised of diverse participants. Friedman

and Sunder (1994) and Harrison and List (2004) are supportive of policy relevant context, however a countervailing view highlights the need for field experiments to address the potential disregard of experimental instructions by subject pools selected to represent target populations or specific behavioural characteristics. Such subject pools can bring to the experimental decision environment prevailing purviews, professional bias and confounding norms and conventions, despite the experimental rules articulated in the instruction sets. Considerations of policy relevance have contributed to a methodological trend combining lab and field experiments to investigate economic behaviour, permitting sharper and more convincing inference (Harrison and List 2004). Harrison and List (2004) suggested classifying criteria for a field experiment taxonomy are (1) the nature of the participant pool, (2) the information or expertise brought to the experiment by the participants, (3) the specificity of the commodity (the absence of abstraction), (4) the nature and realism of the task, (5) the stakes involved, and (6) the environment in which the experiment takes place.

Contextualization is not usual experimental protocol; however this research follows the lead of Cardenas (2000), Krause *et al.* (2003), Poe *et al.* (2004) and Tisdell *et al.* (2004). As an important insight from cognitive psychology, Lowenstein (1999) and Loomes (1999) advocate that decision making is highly context dependent. This has lead some experimentalists to conclude that to inform policy meaningfully, experiments may need to be designed to include salient features of the policy setting of interest (Lowenstein, 1999; Loomes 1999; Krause *et al.* 2003, Tisdell *et al.* 2004). Adherents conclude that while experiments designed to eliminate any confounding effects are useful for isolating influence of single treatment factors, they may not tell us much about how people are likely to react in real world contexts where confounding factors exist. There is now a growing body of experiments conducted in context rich environments. Results demonstrate that differences in context lead to differences in bargaining behavior; risk-taking and sharing (*inter alia* Camerer and Lowenstein 2004, Gintis 2000, Krause *et al.* 2003). While experiments from context rich settings may allow only limited inference about behavior in other contexts, they are employed in this work because they represent in the view of some, the most appropriate way to draw inferences about behavior that are valid for specific contexts where policy design is being investigated (Lowenstein 1999; Plott and Porter 1996).

The policy issue investigated is the management of surface water as a common pool resource, contingent on constitutionally specified objectives and subject to the behavior of individuals with potentially non-market and social motivations. Past research suggests that behavior may diverge substantially from expected utility theoretical predictions of the outcomes of trade, extending to trade in water (Ostrom 1998, Ostrom *et al.* 1992, Gintis 2000, Tisdell *et al.* 2004, Poe *et al.* 2004). According to Vatn and Bromley (1995), Lowenstein (1999) and Loomes (1999) the expression of individual preferences in market settings is a complex psychological process where personal welfare may not be sufficient to explain the nature of choice, especially in the domain of public goods and environmental quality. Additionally, it may not just be individual choice but a variable sequence of choices (Kahneman and Tversky, 1979) potentially filtered through the focal length of collective choice (Ostrom 1998). Prestige, public recognition, group belonging, avoidance of group sanction, and desire to contribute to the public good can all represent powerful motivators in some contexts (Camerer and Lowenstein 2003)

On the basis of the theoretical research in experimental economics this research examines applied economic policy, which requires more realistic simulations of economic environments that depend closely on policies developed to account for the social, economic, and biophysical complexities of water as a common pool resource. Water extraction for irrigation in many river systems is adversely altering the flow pattern, resulting in an environmental externality. In this study the cost of the

externality is socialized equally among the water extractors. This research explores the way farmers may react to such a common pool problem compared with students in replicate experimental settings. The research is funded from a consortium of state and federal water authorities that requires high levels of contextualization to achieve external validity and thus acceptance of the research results. In the experiments, student and irrigator participants acted as farmers extracting water from a river system to grow an irrigated crop. As farmers, participants faced monthly water demands, uncertain rainfall, possible crop loss, and the possibility of trading in water entitlements.

2 RESEARCH QUESTIONS AND HYPOTHESES

The research questions and hypotheses explored were concerned with the common pool nature of riverine environments. Water extraction in many river systems adversely impacts on the flow regime, resulting in an environmental externality. Research by Ostrom (1990, 1998) suggests that common pool resources can be effectively managed if there are information and communication options available to those using the resource. Options for sanctions imposed on those who default on a group strategy are also possible and may reinforce cooperative strategies (Ostrom *et al.* 1992, Posner and Rasmusen 1999). This research builds on the work by Ostrom *et al.* (1992) and Posner and Rasmusen (1999) by questioning in a context-specific laboratory environment the following hypotheses. To explore the effects of subject pool context, we compare the behavioural responses of irrigators in field experiments with those observed of students in laboratory experiments. Behavioural responses were enumerated as the value of an environmental levy and participant incomes.

In Tisdell *et al.* (2004) we explored a number of Hypotheses:

Hypothesis 1 is as follows: Providing aggregate extraction information will not significantly modify extraction levels to produce greater accordance with the environmental flow regime. The notion is that providing only aggregate information on extraction, a common practice, is too crude to provide individual players with sufficient information to consider coordination possible. Aggregate extraction above the environmental target, for example, may result in all players reducing their extraction, which because of a lack of coordination, may result in an equal problem of less than required flow regime.

Hypothesis 2 is as follows: Allowing face to face communication between players on extraction will allow social contracts to form to minimize the environmental externality. The coordination problem proposed in hypothesis 1 may be overcome by providing a forum for communication between the players on issues of extraction.

Hypothesis 3 is as follows: Providing individual extraction information and opportunities for players to communicate will further enforce the social contract and minimize the environmental externality. The notion is not to enforce a penalty, but through social pressure arising from providing individual extraction information, players will conform to the environmental flow objective. In essence, the public provision of individual extraction information and a forum for discussion will give rise to potential verbal peer sanctions.

The ability of players to coordinate their extractions or free ride will, in part, depend on the stability of the distribution of water extraction entitlements through time. At the same time as governments are exploring social interactions of this nature they are also expanding markets for water extraction entitlements as a mechanism for promoting more efficient use of available water supplies under a variety of auction structures including closed and open call auctions. In a closed call market, potential buyers submit sealed bids to buy, and potential sellers submit sealed offers to sell. The

market is ‘‘called,’’ and trades are executed by a clearinghouse, in this case the water authority, at a competitive equilibrium price. The authority notifies successful traders and releases the market price and volume traded information only. In open call markets, all the bids and offers are made public. Market theory would suggest that increasing market knowledge during an open call trading period would increase the level of trade and market efficiency. An open call auction is one in which the bids to buy and sell are publicly available as they are lodged. Tisdell *et al*. (2004) detail the comparison of open and closed call markets in student experiments. Resource constraints limited field and lab comparisons to a closed call market.

The short-term leasehold water markets, which dominate water trade in countries such as Australia, are susceptible to changes in localized weather conditions and crop-watering demands during each season. These markets therefore introduce a level of uncertainty into rates of water extraction and thus may confound strategies to coordinate or promote free riding. The working hypothesis is that the introduction of a closed call auction will result in higher levels of economic efficiency compared to no trade. Each treatment was therefore blocked to take account of the impact of trade and auction structures.

The hypotheses and associated issues led to the development of four treatments within each market environment. The experimental treatments comprised three incremental sets of information levels presented to the participants and a no-information control. The first treatment tested for behavioural changes of participants when presented with real time data of aggregate abstractions compared to the natural flow regime of the experimental setting. The notion is that simultaneously informing the group of monthly natural flows, monthly aggregate extractions, and the associated environmental levy will encourage participants to coordinate extraction to reduce subsequent environmental costs.

The second treatment explored the effect of group communication and the development and implementation of voluntary, cooperative social contracts to reconcile the difference between natural flows and aggregate abstractions. In this context the traders were given time to discuss the nature of the levy prior to commencement of the experiment. Players were given the option of either equal proportional changes or individually determined changes in monthly extraction volumes. Both experimental groups decided by consensus to implement voluntary individual changes in monthly extraction levels. Individual behavioural responses were expressed experimentally as monthly aggregate extraction volumes. Each month, following a period of discussion, participants voluntarily committed to water extraction targets prior to the announcement of their actual monthly farm-specific rainfall, thereby internalizing the risk of rainfall variability on the individual participants. The research hypothesis predicts that monthly discussion sessions will reduce the environmental cost of aggregate extractions.

Finally, the disclosure of individual extraction levels as a form of sanction, therefore reinforcing agreed aggregate extraction targets, will facilitate further reductions in the level of the environmental cost. The hypothesis therefore is that the treatment introducing identification of contract defaulters and the possibility of verbal peer sanctions will reduce the level of environmental costs.

3 EXPERIMENTAL DESIGN

A complete block design was used with the four common pool resource treatments and three market structures (including a no-trade structure). The experimental design is presented in Table 1.

Table 1 Experimental Design

Treatments	No information	Aggregate Information	Aggregate Information and Discussion	Aggregate Information, Discussion and Sanctions
No trade	2 lab sessions *1 field session*	2 lab sessions *1 field session*	2 lab sessions	2 lab sessions *1 field session*
Closed call	2 lab sessions *1 field session*	2 lab sessions *1 field session*	2 lab sessions *1 field session*	2 lab sessions *1 field session*

Tisdell *et al.* (2004) used two groups of 12 student traders were involved in simultaneously replicated experiments. In this study, two groups of irrigators were involved in the field experiments; one group from the Daly River-Katherine region and one from peri-urban region of Darwin. Each group traded for 1 year for each treatment and block combination, a total of eight years of trading, each year taking approximately 2 hours. An experimental session simulated a whole year of monthly trading in the water markets. In aggregate a total of 23 years of water trade and extraction was simulated during the experiments.

3.1 CHARACTERISTICS AND SELECTION OF STUDENT PARTICIPANTS

Student subjects used in Tisdell *et al.* (2004) were recruited from Griffith University (Brisbane, Australia) through advertising billboards and posters placed across the campus and a designated website. As the experimental environment was quite complex and the students had no natural affinity with the issues at hand (recruited from the student population at an urban university), the students were taken through an extensive series of training sessions in the experimental procedures and protocols prior to the experiment. The students were well trained in the principles of trading water entitlements and managing a model farm. The students were not exposed to the more salient issues, such as an environmental externality and ability to communicate, prior to the experiment formally beginning. Throughout the experimental sessions, instructors were on hand to answer procedural questions.

3.2 CHARACTERISTICS OF THE FIELD CATCHMENT AND PARTICIPANTS

Irrigator participants were recruited in extensive consultation with Government horticultural and agricultural agencies and local Peak Body farmer groups, negotiated over a six month period. One subject pool was comprised of 12 irrigators from the Daly River/Katherine district (see Figure 1) and another subject pool from the Darwin area. In contrast with students, irrigator participants had no prior experience with water trading, although are clearly familiar with decisions associated with faming enterprises. Both groups were presented with a single no-trade no-aggregate information session to control for instruction set understanding and to facilitate experimental familiarity. The sessions were held in a local community centre and Government research centre. Access to the experimental software used in the student sessions was accomplished using a series of wireless networked laptop computers and a mobile broadband internet connection. All instruction sets, access to instructors, farm characteristics and experimental protocols were identical to those employed in the student sessions. Irrigator payments were in the accord with the algorithms imputed to calculate student payments, adjusted by a scalar of two for both income and the environmental levy.

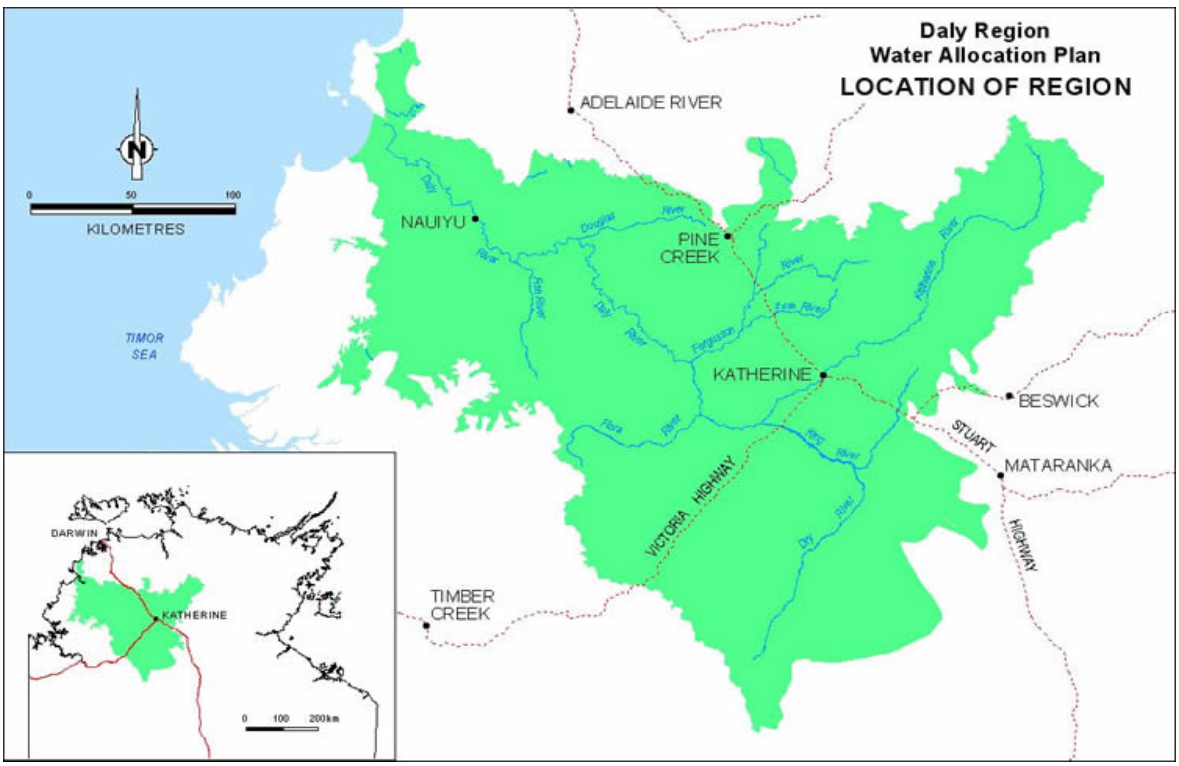

Figure 1 Map of the Daly River Region (Northern Territory Department of Infrastructure Planning and Environment, 2004)

3.3 MARKET ENVIRONMENT

The experimental environment developed in Tisdell *et al.* (2004) involved players acting as irrigators with options concerning the management of a model farm inclusive of options for trading water. To avoid administrator presentation bias or instructor nuance, participants accessed treatment-specific instructions by logging on to the experimental Web site, scrolling through a Power-Point™ slide series, and following the prescribed screen prompts. A complete set of PowerPoint instructions are available from the author on request. The slideshow presentations varied according to the treatment combination in each session, with slides added for each successive treatment. Participants accessed a computer network link at the end of the instruction slides that allowed them to log on to the experiment session. The experimental sessions were conducted using an experimental water-trading program known as Mwater, an experimental economics software package available for use by staff, students, and visitors to the laboratory at Griffith University. Through the Mwater package, participants viewed their general farm characteristics, including their water allocation and crop water requirements. The package also allowed them to trade in a closed clearance market, view their monthly and year-to-date water usage and income tables, and view information on extraction levels according to the treatment requirements of the experiment. Participants were not allowed to talk to each other unless communication was specified in the treatment instruction sets. Participants were provided with a calculator if requested and were also able to use a spreadsheet to perform farm-specific calculations.

3.4 FARM CHARACTERISTICS

Each of the 12 participants in each experimental session was provided with a unique set of model farm characteristics that governed the value of water used on their farm (information on the individual farm characteristics is not reported in order to maintain the integrity of the data for future experiments; further information on the farm characteristics can be obtained from the author), the volume (megaliters (ML), 1 ML = 1.23 acre-feet of water) of allocated water for the year, farm-specific historic median rainfall, and maximum and minimum water requirements for the farm-specific crop in each month. Isolating the important decision variables involved consultation and trials with a large number of farmers in focus groups in southern Australia, attended by approximately 60 farmers. Information was provided both as yearly totals and as monthly figures. The totals, such as the size of each farm's remaining water allocation, were updated monthly as water was applied to the farm's crop and as water was bought or sold. Table 2 displays typical information about each model farm's characteristics that is provided to the participants from the start of the water year.

Table 2 Typical Farm Characteristics

Characteristic	Value
Water supply available	960 ML
Historic usable rainfall to end of year	498 ML
Estimated maximum water needs to end of year	1275 ML
Estimated minimum water needs to end of year	1020 ML
Marginal value of water	$97
Traders income total	$10

All values except for the ''marginal value of water'' are updated monthly. The general consensus of the farmers involved in field trials during development was that state and federal agencies provide them with typical farm budget data (e.g., gross margins). It is this data that farmers focus on in the first instance, and it is up to the farmers to realize the increasing opportunity cost of not continuing to irrigate once the decision to progressively invest water in a crop is made. As this is something that is learnt by farmers (especially when they suffer crop loss) rather than information provided to them, the advice given was to leave the reported marginal value of water constant and include the notion of increasing marginal value through the threat of crop loss and associated lost income. Table 3 is an example of a water use table displaying water requirements for each month. Actual rainfall is provided before each irrigator decides how much water to use from their allocation in that month. Allocated and total water use are displayed for all previous months.

3.5 CROP LOSS

Players faced uncertainty of rainfall and possible crop loss. ''Crop loss'' refers to any lost potential income caused by irrigating less than the minimum crop water requirements. If monthly minimum water requirements were met, the whole crop was maintained. However, if total water use was less than the minimum crop water requirements in any month, then the area of crop was proportionally reduced. The potential income from the irrigated land left fallow was lost for the whole year. New minimum and maximum water requirements were then provided for the rest of the year. Rainfall was also reduced accordingly.

Table 3 A Typical Water Use Table

Month	Historic Median Rainfall	Maximum Water Usage	Actual Rainfall	Allocated Water Used	Total Water Use	Minimum Crop Water Requirements	Qty sold	Qty bought
OCT	52	214	49	148	197	171		200
NOV	36	198	38			158		
DEC	48	186				149		
JAN	46	169				135		
SEP	0	0				0		

3.6 INCOME CALCULATIONS

With increasing community involvement and empowerment of self-regulation as a mechanism for implementing water policy it is necessary to explore the level of accordance with group agreements and the impact of supplying environmental information. The nature of the damage caused to riverine ecosystems is a social cost borne by all in the community. In the experiments this is measured by the value of the environmental levy. Participants received A$10 turn up payment plus the traders' income earned during each experiment. The monthly farm income equalled total water usage times their marginal value of water, less crop loss, plus the income from the sale of water less the cost of water bought. Through a series of exchange rates, farm incomes were converted to traders' income in order to account for differences in farm sizes and characteristics. Table 4 displays a typical farm income table, including the values for market clearance prices and farm and trader's income. Irrigators were paid according to same performance algorithm multiplied twofold.

Table 4 Typical Farm Income Table

Characteristic	**Value**
Month	October
Total water usage	197
Monthly income from crop	19109
Crop loss	0
Equilibrium price	60
Cost of water bought	12000
Total monthly income	7109
Trader's income	7.12

3.7 ENVIRONMENTAL LEVY

In the experiments an environmental levy was introduced to create an experimental environment in which an individual's payoff depended both on their own actions and the actions of all other

members of their group. The experimental river system consists solely of the 12 players' farms. The important environmental attribute of the system is located upstream of the farms. The flow upstream is completely dependent on the monthly aggregate extractive demand of the players. Consistent with the utilization of a common pool resource, an individual player's final payment was comprised of the proceeds from their farm income (namely, farm and trading activities) less their proportional share of the costs of a change in riverine environmental services. A change in environmental services is measured as a change in natural flows resulting from the extraction of irrigation water. The monthly volume of natural flows reflects the experimental catchment's historic median environmental flows and is illustrated in Figure 1. The imposed environmental levy creates a system of incentives in the experiment consistent with the interdependency imposed by environmental externalities. The levy was one trader dollar per 100,000 units, calculated as the squared difference between aggregate extraction and historical median environmental flows (1) as shown in Figure 1.

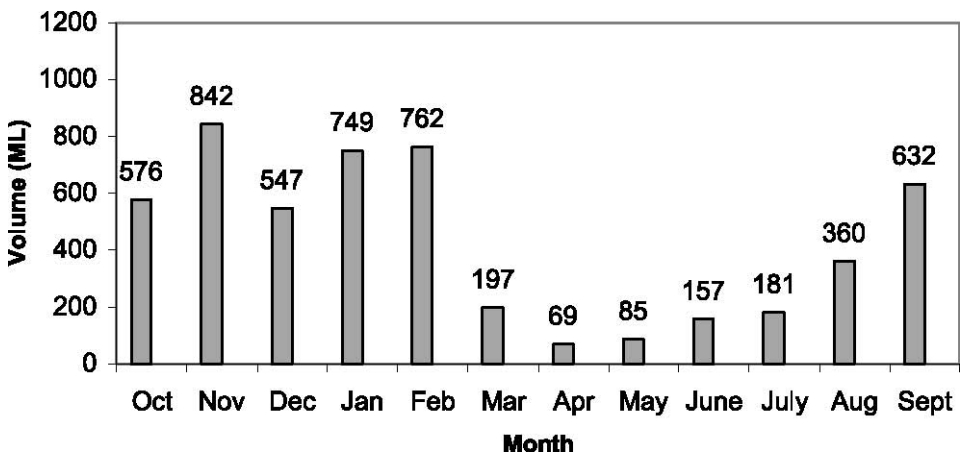

Figure 1 Historic median environmental flows.

$$\text{Environmental levy} = \frac{\sum_{t=1}^{12}(AggExtraction_t - Naturalflow_t)^2}{100{,}000} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The value of the environmental levy reflects increasing marginal environmental damages as the divergence between natural flows and extraction increases (Figure 2). This means that each additional ML of allocated water used by any individual farmer had a proportionally greater environmental cost. These data and methodologies developed in Tisdell *et al.* (2004) were taken into the field. The results reported in this paper compare the student-based experimental results reported in Tisdell *et al.* (2004) with those derived from experimental sessions conducted in the Northern Territory of Australia.

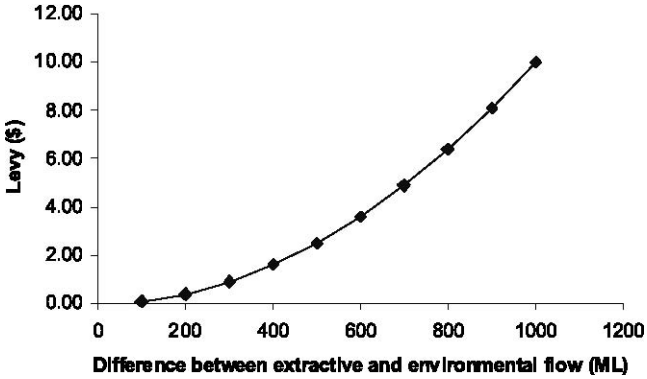

Figure 2 the calculated value of the experimental environmental levy.

4 RESULTS

This section reports the findings of the research. Three metrics were used to evaluate the experimental results: (1) the level of accordance with environmental targets, measured by the environmental levy, (2) the average farmer income measured by trader's income, and (3) the ratio of trader's income to environmental levy. Received wisdom suggests that the implications of laboratory findings should be interpreted cautiously beyond the specific institutional setting of the experiment.

4.1 IMPACT OF THE PROVISION OF INFORMATION, DISCUSSION FORUMS, AND SANCTIONS ON MEETING ENVIRONMENTAL TARGETS

It is expected that the level of environmental damage caused by water extraction will increase as a result of trade and decline with information, discussion, and individual extraction disclosure. Table 5 presents the combined results of the 2 sessions of student experiments and the one session of field experiments. Compared to no-trade treatments, the closed call auction student experiments resulted in the average levy increasing from $4.13 to $6.16, compared to an increase in the field experiments of a similar magnitude; from $3.91 to $7.49.

Table 5 Information/Communication and Trade Treatments: Environmental Levy Mean Values [a]

	No Information, $		Aggregate Information, $		Aggregate Information and Discussion, $		Individual Information and Discussion, $		Average $	
	Lab	*Field*	Lab	*Field*	Lab	*Field*	Lab	*Field*	Lab	*Field*
No Trade	5.48	*4.65*	5.03	*3.84*	2.71	*NA*	3.30	*3.25*	4.13	*3.91*
Closed Call	7.62	*6.21*	6.28	*10.51*	4.52	*9.65*	6.20	*3.62*	6.16	*7.49*
Average	6.28 (a)	*5.43*	5.65 (a)	*7.17*	3.91 (b)		4.65 (ab)	*3.44*		

[a] The study by Tisdell *et al.* (2004) used statistical analysis of the environmental levies arising from the experiments found significant differences in the levies between the trade and no-trade treatments at $\alpha = 0.05$. As only a single replicate of the field experiments was possible, statistical analysis of the field experiments was not possible. Information/communication treatment means with the same letter in parentheses were not statistically different at $\alpha = 0.05$. Trade treatment means with the same letter in parentheses were not statistically different at $\alpha = 0.10$.

Coordinating individual actions to converge with environmental targets is difficult if aggregate extraction information is provided without a means of communication. In the student experiments, providing only aggregate information did not produce a statistically significant change in the

environmental levy compared to no information, whereas providing aggregate information with communication produced a statistically significant reduction in the environmental levy compared to no information or aggregate information only. It was hypothesized that the public provision of individual extraction information and a forum for discussion would give rise to potential verbal peer sanctions and greater conformity to the environmental flow target. This did not occur. The environmental levy in experimental environments involving individual information and discussion were not statistically different to environments where participants were provided with no information or aggregate information with or with communication.

There was a substantial levy increase in the market plus aggregate information treatment compared to market/no information treatment in the field sessions ($6.21 to $10.51) and a small levy reduction ($10.51 to $9.65) when the discussion treatment was introduced. The no trade treatment was characterised by relatively constant levy values across the treatments. In contrast to the student sessions, the public disclosure of individual extractions substantially decreased the levy in the market treatment, a reduction from $9.65 to $3.62. In summary, it appears that the environmental damage arising from water extraction is minimized in environments where there is no trade and farmers are provided with aggregate extraction information and a forum for discussion. In the field sessions, the public disclosure of extraction proved an important instrument in reducing the environmental damage resulting from irrigation activity when participants are able to exchange tradeable water rights in the market treatment.

4.2 IMPACT OF THE PROVISION OF INFORMATION, DISCUSSION FORUMS, AND SANCTIONS ON AGGREGATE TRADERS' INCOME

Traders' incomes were calibrated to ensure equal potential income and used to compare the impact of the various treatments and auction structures. Table 6 presents the average trader's income for each treatment/block combination. In terms of trade, there was no statistical difference in the average student income earned when there was no trade compared to experiments involving the closed call market. A similar result was observed in the field sessions.

Discussion with aggregate or individual information led to statistically higher levels of average student traders' income compared to no information. A similar increase from $25.80 to $32.46 ($33.26 in the public disclosure of individual information treatment) was observed for the field session for the same market treatments. In the same vein as the environmental levy, there was no statistical difference in average student income between no information and the provision of aggregate information. In contrast, income increased substantially in the field no-trade treatment when aggregate information was introduced ($27.95 to $35.36) and decreased in the closed call market treatment ($30.42 to $25.80). There was no statistical difference in average income between the provision of aggregate information, with or without discussion, and the provision of individual information with discussion. The income from the field sessions was generally less than those observed in the student sessions.

What the student results suggest is that the provision of aggregate information alone does not contribute to improvements in the environmental flow or average income, the introduction of a closed call market trade results in worsening environmental conditions and, does not significantly improve average incomes. The field results suggest a similar result.

Table 6 Information/Communication and Trade Treatments: Mean Trader's Income

	No Information $		Aggregate Information, $		Aggregate Information and Discussion, $		Individual Information and Discussion, $		Average $
	Lab	*Field*	Lab	*Field*	Lab	*Field*	Lab	*Field*	Lab
No Trade	38.10	*27.95*	39.55	*35.36*	43.20	*NA*	42.88	*32.31*	40.94 (a)
Closed Call	40.71	*30.42*	44.26	*25.80*	44.28	*32.46*	46.17	*33.26*	43.85 (a)
Average	41.35 (d)		42.34 (de)		45.72(e)		45.55 (e)		

[a] Treatment means with the same letter in parentheses were not statistically different at $\alpha = 0.05$.

4.3 RATIO OF INCOME AND ENVIRONMENTAL LEVIES

Trade-offs between maximizing extractive income and riverine environmental flow regimes is common. One metric to measure that trade-off is the income per unit of environmental damage. It can be seen from Table 7 that providing aggregate information and a forum for discussion without trade maximized the return per unit of environmental damage in the student sessions. Providing individual information and a forum for discussion without trade maximized the return per unit of environmental damage in the field sessions. In the student sessions, compared to aggregate information and discussion, providing individual information provided lower returns per unit of environmental damage and was therefore counter productive in all cases. The worst student return per unit of environmental damage results from withholding information in a closed call market environment and providing aggregate information in a closed call market in the field session.

Table 7 Environmental Ratios

Treatment	**Market type**	**Income**	**Levy**	**Ratio**
Laboratory Experiments				
Aggregate information and discussion	No trade	43.20	2.71	15.94
Individual information and discussion	No trade	42.88	3.30	13.00
Aggregate Information	No trade	39.55	5.03	7.87
Aggregate Information	Closed Call	44.26	6.28	7.05
Individual information and discussion	Closed Call	46.17	6.59	7.01
No information	No trade	38.10	5.48	6.96
Aggregate information and discussion	Closed Call	47.25	7.44	6.35
No information	Closed Call	40.71	7.62	5.34
Field Experiments				
Individual information and discussion	No trade	32.31	3.25	9.94
Individual information and discussion	Closed call	33.26	3.62	9.72
Aggregate Information	No trade	35.36	3.84	9.21
No Information	No trade	27.95	4.65	6.05
No Information	Closed Call	30.42	6.21	4.90
Aggregate information and discussion	Closed Call	32.46	9.65	3.36
Aggregate Information	Closed Call	25.80	1051	2.55

4.4 ENVIRONMENTAL AGREEMENTS AND ACCORDANCE

During the discussion period, participants were able to form agreements on aggregate extraction. Information on their aggregate agreement and aggregate extraction was provided. In the final series of experiments, individual agreement and extraction variations were provided. The level of accordance reported in Table 8 is based on the inverse sum squared difference between the monthly aggregate agreement and aggregate extraction. The level of accordance with the agreement was greatest in no trade with individual information and discussion experiments. Provision of aggregate information led to higher levels of accordance in closed call experiments compared to open call experiments. In contrast, open call experiments produced higher levels of accordance in experiments where individual extractions were disclosed. Disclosure of the agreed and actual individual extractions improved the level of accordance in the no trade and open call experiments but not in the closed call experiments. The lowest level of accordance occurred in the closed call market with individual information experiments.

In the field experiments accordance was lower in the closed call aggregate information treatment compared to the student session. In contrast to the student sessions, the public disclosure of individual extraction, relative to the agreed extraction, substantially increased the accordance levels compared to the aggregate information treatment. The enumerated level of voluntary accordance observed in the field sessions involving the public disclosure of individual information treatment was substantially higher than that observed in the student sessions. High levels of accordance in the field sessions were observed for both the no-trade and closed call treatments.

Table 8 Level of Accordance with Agreements[a]

	Aggregate information and discussion		Individual information and discussion	
	Student	*Field*	Student	*Field*
No trade	0.0165		0.0241	*0.166736*
Closed	0.0128	*0.000006*	0.0100	*0.379902*

[*] Accordance measure= $\dfrac{1}{\sum_{t=1}^{12}(aggAgree_t - aggExtract_t)^2}$

5 CONCLUSION

Experimental economics yields a formalized, replicable approach to rapidly assess alternate policy directives, typically expressed as market outcomes, prior to catchment-wide implementation (Dinar *et al.*, 1998). The methodology provides a relatively inexpensive means of institutional analysis coupled with substantially reduced time horizons. This research examined applied economic policy, which requires more realistic simulations of economic environments that depend closely on policies developed to account for the social, economic, and biophysical complexities of water as a common pool resource. To enable this complex analysis to occur, this project has developed a number of methodical systems, inclusive of extensive survey design and analysis to experimental economics.

A generally received wisdom notes that the implications of laboratory findings should be interpreted cautiously beyond the specific institutional setting of the experiment. In applying the findings of this research to specific catchments one should always be mindful of the particular

characteristics of the catchment and the transaction costs and possible institutional constraints and opportunities associated with providing an effective forum for group communication and the dissemination of information.

The magnitude, direction and sign of the between treatment field results were generally in accord with the student laboratory sessions. The increased level of the environmental levy, a corollary of the closed call treatment combined with aggregate information and the substantial reduction in the levy associated with the introduction of individual information were notable diversions. The level of voluntary accordance with the group crafted social compact was also substantially higher in the field experiments compared to the student sessions. An improved understanding of social connections, group norms, reputation and reciprocity in the field settings and the translation into policy praxis is the subject of ongoing research, as is the comparison of student-based laboratory experiments with those in the field.

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